Chapter 8
Special Features

Section I
Pipelines and Other Utility Lines Crossing Levees

8-1. General Considerations

a. Serious damage to levees can be caused by inadequately designed or constructed pipelines, utility conduits, or culverts (all hereafter referred to as "pipes") beneath or within levees. Each pipe crossing should be evaluated for its potential damage which would negatively impact the integrity of the flood protection system and could ultimately lead to catastrophic failure. During high water, seepage tends to concentrate along the outer surface of pipes resulting in piping of fill or foundation material. High water also results in uplift pressures that may cause buoyancy of some structures. Seepage may also occur because of leakage from the pipe. In the case of pipes crossing over levees, leakage can cause erosion in the slopes. In addition, loss of fill or foundation material into the pipe can occur if joints are open. The methods of pipe installation should be understood by the designer to anticipate problems that may occur. Some of the principal inadequacies that are to be avoided or corrected are as follows:

(1) Pipes having inadequate strength to withstand loads of overlying fill or stresses applied by traffic.

(2) Pipe joints unable to accommodate movements resulting from foundation or fill settlement.

(3) Unsuitable backfill materials or inadequately compacted backfill.

(4) High pressures from directional drilling that could result in hydro-fracturing the surrounding materials.

b. Some state and local laws prohibit pipes from passing through or under certain categories of levees. As a general rule, this should not be done anyway, particularly in the case of pressure lines. However, since each installation is unique, pipes in some instances may be allowed within the levee or foundation. Major factors to be considered in deciding if an existing pipe can remain in place under a new levee or must be rerouted over the levee, or if a new pipe should be laid through or over the levee are as follows:

(1) The height of the levee.

(2) The duration and frequency of high water stages against the levee.

(3) The susceptibility to piping and settlement of levee and foundation soils.

(4) The type of pipeline (low or high pressure line, or gravity drainage line).

(5) The structural adequacy of existing pipe and pipe joints, and the adequacy of the backfill compaction.

(6) The feasibility of providing closure in event of ruptured pressure lines, or in the event of failure of flap valves in gravity lines during high water.

(7) The ease and frequency of required maintenance.

(8) The cost of acceptable alternative systems.

(9) Possible consequences of piping or failure of the pipe.

(10) Previous experience with the owner in constructing and maintaining pipelines.

General criteria for pipes crossing levees are given in Table 8-1.

Table 8-1
Criteria for Pipelines Crossing Levees

Pipelines	Leaving Existing Pipeline in Foundations of Proposed Levees	New Pipeline Installation: Pipes Through Levees	New Pipeline Installation: Pipes Over Levees
Must be known to be in good condition	X		
Must have adequate strength to withstand levee loading	X	X	
Must have adequate cover as needed to prevent damage by vehicular traffic or heavy equipment			X
Must have adequate cover for frost protection			X
Must have sufficient flexibility in joints to adjust under expected settlement and stretching of pipe	X	X	X
Pressure lines must have provisions for rapid closure in event of leakage or rupture	X	X	X
Gravity discharge pipes must have provisions for emergency closure in event of inoperative flap valves on riverside end	X	X	
Must have pervious backfill under landside third of levee where:			
a. Foundation materials are susceptible to piping	X		
b. Levee materials are susceptible to piping		X	

8-2. General Considerations for Pipelines Crossing Through or Under Levees

a. General. As has been noted previously, it is preferable for all pipes to cross over a levee rather than penetrate the embankment or foundation materials. This is particularly true for pipes carrying gas or fluid under pressure. Before consideration is given to allowing a pressure pipe (and possibly other types of pipe) to extend through or beneath the levee, the pipe owner should provide an engineering study to support his request for such installation. The owner, regardless of the type of pipe, should show adequate capability to properly construct and/or maintain the pipe. Future maintenance of pipe by the owner must be carefully evaluated. It may be necessary to form an agreement to the effect that should repairs to a pipe in the levee become necessary, the pipe will be abandoned, sealed, and relocated over the levee.

b. Existing pipes

(1) All existing pipelines must be located prior to initiation of embankment construction. As previously noted, inspection trenches may reveal abandoned pipes not on record. It is preferable that all abandoned pipes be removed during grubbing operations and the voids backfilled. Any existing pipe should meet or be made to meet the criteria given in Table 8-1. If this is not feasible and removal is not practical, they should be sealed, preferably by completely filling them with concrete. Sealed pipes must also meet the criteria given in Table 8-1 relating to prevention of seepage problems.

(2) In general, existing pressure pipes should be relocated over the proposed new levee. Rupture or leakage from such pipes beneath a levee produces extremely high gradients that can have devastating effects on the integrity of the foundation. Therefore, as indicated by the criteria in Table 8-1, it is imperative that pressure pipes be fitted with rapid closure valves or devices to prevent escaping gas or fluid from damaging the foundation.

(3) Although gravity drainage lines may be allowed or even required after the levee is completed, it is likely that existing pipes will not have sufficient strength to support the additional load induced by the embankment. Therefore, existing pipes must be carefully evaluated to determine their supporting capacity before allowing their use in conjunction with the new levee.

c. New Pipelines. Generally, the only new pipelines allowed to penetrate the foundation or embankment of the levee are gravity drainage lines. The number of gravity drainage structures should be kept to an absolute minimum. The number and size of drainage pipes can be reduced by using such techniques as ponding to reduce the required pipe capacity.

8-3. General Considerations for Pipelines Crossing Over Levees

In the past the term and concept of freeboard was used to account for hydraulic, geotechnical, construction, operation and maintenance uncertainties. Pipelines crossing over the levee were encouraged to be within the freeboard zone to reduce or eliminate many of the dangers that are inherent with pipelines crossing through the embankment or foundation. The term and concept of freeboard to account for these uncertainties is no longer used in the design of levee projects. Therefore, since freeboard no longer exists, pipes must cross over the completed levee cross section. Problems do exist, however, with pipelines crossing over the levee. These pipes must be properly designed and constructed to prevent (a) flotation if submerged, (b) scouring or erosion of the embankment slopes from leakage or currents, and (c) damage from debris carried by currents, etc. In some areas climatic conditions will require special design features. Guidance on design methods and construction practices will be given later in this chapter.

8-4. Pipe Selection

a. EM 1110-2-2902 contains a discussion of the advantages and disadvantages of various types of pipe (i.e., corrugated metal, concrete, cast iron, steel, clay, etc.). The selection of a type of pipe is largely dependent upon the substance it is to carry, its performance under the given loading, including expected deflections or settlement, and economy. Although economy must certainly be considered, the overriding factor must be safety, particularly where urban levees are concerned.

b. The earth load acting on a pipe should be determined as outlined in EM 1110-2-2902. Consideration must also be given to live loads imposed from equipment during construction and the loads from traffic and maintenance equipment after the levee is completed. The respective pipe manufacturers organizations have recommended procedures for accounting for such live loads. These recommended procedures should be followed unless the pipe or roadway owners have more stringent requirements.

c. Required strengths for standard commercially available pipe should be determined by the methods recommended by the respective pipe manufacturers organizations. Where cast-in-place pipes are used, design procedures outlined in EM 1110-2-2902 should be followed. Abrasion and corrosion of corrugated steel pipe should be accounted for in design using the method given in Federal Specification WW-P-405B(1) (Appendix A) for the desired design life. The design life of a pipe is the length of time it will be in service without requiring repairs. The term does not imply the pipe will fail at the end of that time. Normally, a design life of 50 years can be economically justified. Corrugated pipe should always be galvanized and protected by a bituminous or other acceptable coating as outlined in EM 1110-2-2902. Protective coatings may be considered in determining the design life of a pipe.

d. Leakage from or infiltration into any pipe crossing over, through, or beneath a levee must be prevented. Therefore, the pipe joints as well as the pipe itself must be watertight. For pipes located within or beneath the embankment, the expected settlement and outward movement of the soil mass must be considered. Where considerable settlement is likely to occur the pipe should be cambered (para 8-7). Generally, flexible corrugated metal pipes are preferable for gravity lines where considerable settlement is expected. Corrugated metal pipe sections should be joined by exterior coupling bands with a gasket to assure watertightness. Where a concrete pipe is required and considerable settlement is anticipated, a pressure-type joint with concrete alignment collars should be used. The collars must be designed either to resist or accommodate differential movement without losing watertight integrity. Where settlement is not significant, pressure-type joints capable of accommodating minor differential movement are sufficient. Design details for concrete collars are shown in EM 1110-2-2902. Cast iron and steel pipes should be fitted with flexible bolted joints. Steel pipe sections may be welded together to form a continuous conduit. All pressure pipes should be pressure tested at the maximum anticipated pressure before they are covered and put into use.

e. During the design, the potential for electrochemical or chemical reactions between the substratum materials or groundwater and construction materials should be determined. If it is determined that there will be a reaction, then the pipe and/or pipe couplings should be protected. The protective measures to be taken may include the use of cathodic protection, coating of the pipe, or use of a corrosion-resistant pipe material.

8-5. Antiseepage Devices

a. Antiseepage devices have been employed in the past to prevent piping or erosion along the outside wall of the pipe. The term “antiseepage devices” usually referred to metal diaphragms (seepage fins) or concrete collars that extended from the pipe into the backfill material. The diaphragms and collars were often referred to as “seepage rings.” However, many piping failures have occurred in the past where seepage rings were used. Assessment of these failures indicated that the presence of seepage rings often results in poorly compacted backfill at its contact with the structure.

b. Where pipes or conduits are to be constructed through new or existing levees:

(1) Seepage rings or collars should not be provided for the purpose of increasing seepage resistance. Except as provided herein, such features should only be included as necessary for coupling of pipe sections or to accommodate differential movement on yielding foundations. When needed for these purposes, collars with a minimum projection from the pipe surface should be used.

(2) A 0.45-m (18-in.) annular thickness of drainage fill should be provided around the landside third of the pipe, regardless of the size and type of pipe to be used, where landside levee zoning does not provide for such drainage fill. For pipe installations within the levee foundation, the 0.45-m (18-in.) annular thickness of drainage fill shall also be provided, to include a landside outlet through a blind drain to ground surface at the levee toe, connection with pervious underseepage features, or through an annular drainage fill outlet to ground surface around a manhole structure. Figure 8-1 shows typical sections of drainage structures through levees. Figure 8-2 shows typical precast conduits through the levee.

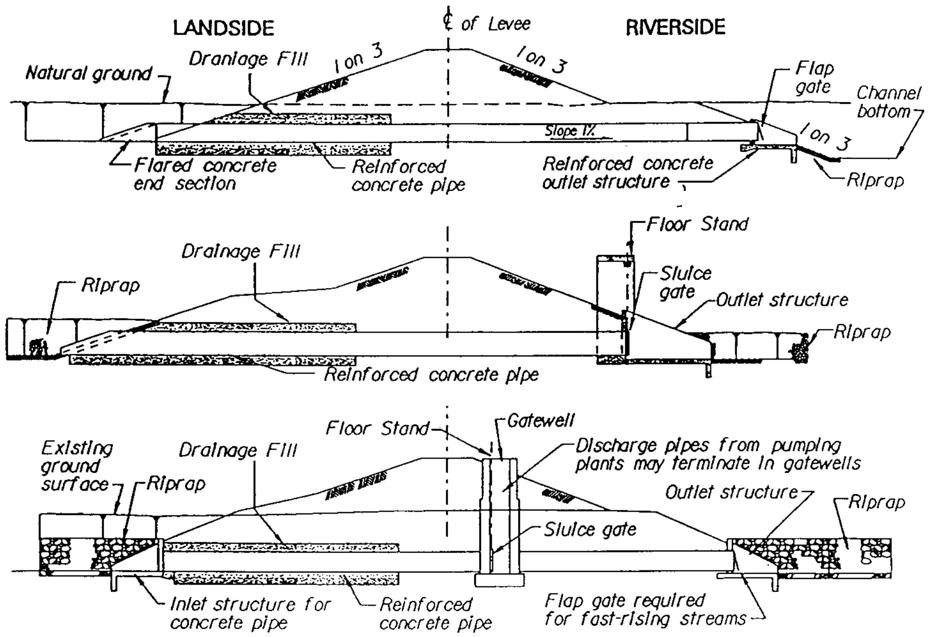


Figure 8-1. Typical sections, drainage structures through levees

8-6. Closure Devices

a. All pipes allowed to penetrate the embankment or foundation of a levee must be provided with devices to assure positive closure. Gravity lines should be provided with flap-type or slide-type service gates on the riverside of the levee. Automatic flap-type gates are usually used where the water is likely to rise to the "Gate Closing Stage" rather suddenly and where the water stage is likely to fluctuate within a few feet above and below the "Gate Closing Stage" for prolonged periods of time during flood season. Automatic gates are also required on slower rising streams or bodies of water where frequent visits from operating personnel are not practical.

b. Slide-type gates are usually preferred as service gates where the rate of rise of the water during major floods is slow, enough (minimum of 12-hr flood prediction time) to give ample time for safe operation. The principal advantages of the slide gate in comparison with automatic flap gates are greater reliability of operation and the ease with which emergency closure can be made in event obstructions prevent closure of the gate. Usually emergency closure can be made by filling the manhole with sandbags. The obvious

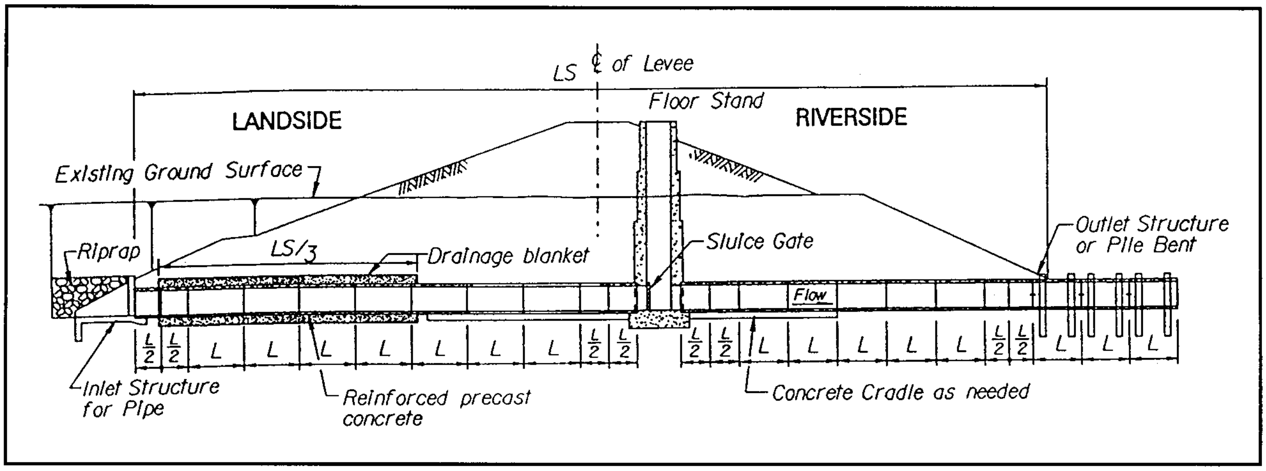


Figure 8-2. Typical precast conduit (levees)

disadvantage of slide type gates is that personnel must be on hand for their operation. Also their initial cost is generally greater than that for a flap-type gate.

c. A slide-type gate with a flap-type gate attachment is often used and affords the advantages of automatic flap gate operation with the added safety of the slide-type gate. Such installations usually eliminate the need for a supplemental emergency gate as described below.

d. Experience has shown that service gates occasionally fail to close completely during critical flood periods because of clogging by debris, mechanical malfunctions, or other causes. This, of course, can cause flooding of, the protected areas. Supplemental emergency gates are intended to minimize these risks insofar as necessary and economically practical. For an emergency gate to be effective it must be located so that its controls are accessible during flood stage. Provisions required for emergency protection of other areas should be consistent with the risks and cost involved.

e. Pressure pipes should be fitted with valves at various stations that can be closed rapidly to prevent gas or fluid from escaping within or beneath a levee should the pipe rupture within these areas. Provisions for closure of pressure pipes on the water side must also be provided to prevent backflow of floodwater into the protected area should the pipe rupture. These requirements should generally be followed in other areas, but may be relaxed to be consistent with the risks and costs involved.

8-7. Camber

The alignment of a gravity structure must be such as to provide for a continuous slope toward the outlet. Settlement of the embankment and foundation can significantly alter the initial grade line of a pipe. Therefore, the expected settlement of the levee must be considered in establishing the initial grade line. If the settlement will result in an upward gradient in the direction of flow or not allow the desired gradient to be maintained, the pipe should be cambered. The amount of camber required can usually be taken as the mirror image of the settlement curve along a line established by the final required grade. The camber should then be laid out, preferably as a vertical curve, on a grade such that all parts of the pipe will slope toward the outlet when installed. If the gradient of the pipe is limited and the camber will initially result in a slope away from the outlet, the portion of the pipe from the inlet up to the point of greatest load may be installed level. The remaining portion of the pipe is then installed on a vertical curve tangent to the first portion of the pipe.

Regardless of the type of pipe selected, movements at the joints must be considered as discussed in paragraph 8-4d.

8-8. Installation Requirements

a. General. The installation of pipes or other structures within the levee or foundation probably requires the greatest care and the closest supervision and inspection of any aspect of levee construction. Most failures of levee systems have initiated at the soil-structure interface and therefore every effort must be made to ensure that these areas are not susceptible to piping. Of overriding importance is good compaction of the backfill material along the structure. Pipes installed by open trench excavation should be installed in the dry and a dewatering system should be used where necessary. Pipes installed by directional drilling, microtunneling, or other trenchless methods require special consideration.

b. Pipes crossing through or beneath levees

(1) The preferred method of installing pipes within the embankment or foundation of a levee has historically been by the open cut method. Preferably, new levees should be brought to a grade about 610.8 mm (2 ft) above the crown of the pipe. This allows the soil to be preconsolidated before excavating the trench. The trench should be excavated to a depth of about 610.8 mm (2 ft) below the bottom of the pipe and at least 1.2 m (4 ft) wider than the pipe. The excavated material should be selectively stockpiled so that it can be replaced in a manner that will not alter the embankment zoning if there is some or will result in the more impervious soils on the riverside of the levee.

(2) After the trench has been excavated, it should be backfilled to the pipe invert elevation. In impervious zones, the backfill material should be compacted with mechanical compactors to 95 percent standard density at about optimum water content.

(3) First-class bedding should be used for concrete pipe and other rigid pipe, as shown in EM 1110-2-2902 except no granular bedding should be used in impervious zones. For flexible pipe, the trench bottom should be flat to permit thorough tamping of backfill under the haunches of the pipe. Backfill should be compacted to 95 percent standard density at about optimum water content. The backfill should be brought up evenly on both sides of the pipe to avoid unequal side loads that could fail or move the pipe. Special care must be taken in the vicinity of any protrusions such as joint collars to ensure proper compaction. Where granular filter material is required, it should be compacted to a minimum of 80 percent relative density. In areas where backfill compaction is difficult to achieve, flowable, low strength concrete fill has been used to encapsulate pipes in narrow trenches.

(4) In existing levees, the excavation slopes should be stable, meet OSHA criteria, but in no case be steeper than 1V on 1H. The excavated material should be selectively stockpiled as was described for new levees. The pipe is installed as described in the previous paragraphs. Impervious material within 0.61 m (2 ft) of the pipe walls should be compacted to 95 percent standard density at optimum water content, with the remainder of the backfill placed at the density and water content of the existing embankment.

(5) Installation of pipes in existing levees by directional drilling, microtunneling, tunneling or jacking may be considered. It is recognized, that in some instances, installation by the open cut method is not feasible or cannot be economically justified. Where trenchless methods are allowed, special considerations are required.

(6) Pipes under levees.

(a) General. Pipes crossing beneath levees also require special considerations. Such crossings should be designed by qualified geotechnical engineers. Pipes constructed with open excavation methods should proceed in accordance with the requirements stated in the above paragraph, Pipes Crossing Through or Beneath Levees. If directional drilling or other trenchless methods are used, seepage conditions may be aggravated by the collapse of levee foundation material into the annular void between the bore and pipe. Penetration through the top stratum of fine-grained materials may concentrate seepage at those locations. Pipes constructed with trenchless methods should proceed only after a comprehensive evaluation of the following: comprehensive understanding of the subsurface soil and groundwater conditions to a minimum depth of 6.1 m (20 ft) below the lowest pipe elevation, locations of the pipe penetration entry and exit, construction procedure, allowable uplift pressures, on-site quality control and quality assurance monitoring during construction operation, grouting of the pipe annulus, backfilling of any excavated areas, and repair and reinstatement of the construction-staging areas. Guidance for construction of pipelines beneath levees using directional drilling is provided in Appendix A of WES CPAR-GL-98-1 (Staheli, et al. 1998). Guidance for construction of pipelines using microtunneling methods is provided in WES CPAR-GL-95-2 (Bennett, et al. 1995).

(b) Pipes installed by directional drilling. The pipe entry or exit location, when located on the protected (land) side, should be set back sufficiently from the land side levee toe to ensure that the pipe penetrates some depth of a pervious sand stratum but is no less than 91.5 m (300 ft) from the centerline of the levee crest. The pipe entry or exit location, when located on the unprotected (river) side, should be located at least 6.1 m (20 ft) riverward of the levee stability control line. This is the distance between the river side levee toe and an eroding bank line which will maintain the minimum design criteria for slope stability.

If directional drilling is to be used, the depth of the pipe under the levee should be at a level to maintain an adequate factor of safety against uplift from the pressurized drilling fluid during the drilling operation. A positive means of maintaining an open vent to the surface should be required whether through bored holes or downhole means while installing the drill pipe.

The drilling fluid should consist of a noncolloidal lubricating admixture to ensure suspension and removal of drilling cuttings. The pilot hole should be advanced at a rate to maintain a continuous return flow. The annular space should be sufficient to ensure that no blockage occurs with the drilling cuttings. The prereamer boring diameter should be of sufficient size to ensure that the production pipe can be advanced without delay and undue stress to the surrounding soils. The prereamer boring operation should be continuous for the down-slope and up-slope cutting segments. Excessive drilling fluid pressures can hydraulically fracture the levee foundation and levee embankment and should be avoided.

Where economically feasible, the pipeline should be bored through rock where the pipeline crosses the levee centerline.

The maximum allowable mud pressure acting against the borehole wall should be evaluated using the Delft equation presented in the Appendix A of WES CPAR-GL-98-1 (Staehli, et al., 1998). During construction, the actual mud pressure existing in the borehole must be measured by a pressure measuring device located on the outside of the drill string no more than 5 ft from the drill bit. The drilling operator should be required to monitor these pressures and adjust the drilling mud pressure so as not to exceed the maximum pressure determined by Delft equation.

Where the casing pipe is carrying multiple fibre optic cables and each cable is installed within its own HDPE inner duct, the detail shown in Figure 8-3a should be used to prevent preferred seepage path (both external and internal). The casing pipe must end in the encasements.

The directional drilling contract should be required to show proof that all of his pressure sensors and readout devices have been calibrated by a national standard within the last 6 months.

A full time inspector, not on directional drilling contractor's payroll, should be required to observe the construction.

The drilling fluid should be processed through an active drilling mud conditioning unit to remove the cuttings from the drill fluid and maintain its viscosity.

c. Pipes crossing over levees. Pipe crossings on the surface of the levee should be designed to counteract uplift of the empty pipe at the design high water stage. This may be accomplished by soil cover, anchors, headwalls, etc. All pipes on the riverside of the levee should have a minimum of 305 mm (1 ft) of soil cover for protection from debris during high water. It is desirable for pipe on the landward side to also be covered with soil. Pipes crossing beneath the levee crown should be provided with sufficient cover to withstand vehicular traffic as outlined in paragraph 8-4b. Depth of cover should also be at least the depth of local frost protection. Where mounding of soil over the pipe is required, the slope should be gentle to allow mowing equipment or other maintenance equipment to operate safely on the slopes. The approach ramps on the levee crown should not exceed 1V on 10H in order to allow traffic to move safely on the crown. The trenching details for pipelines cross-up and over-levees are shown in Figure 8-3b and Figure 8-3c.

Section II
Access Roads and Ramps

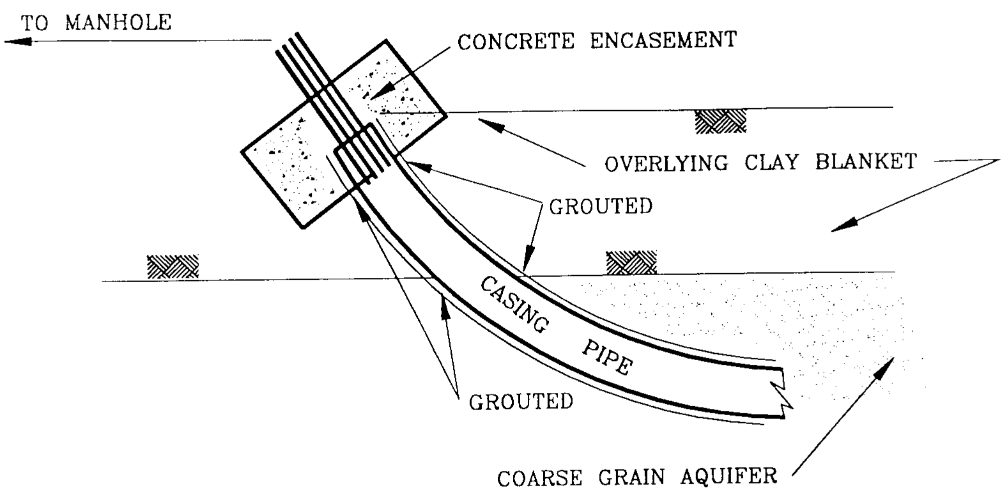
8-9. Access Roads

a. Access road to levee. Access roads should be provided to levees at reasonably close intervals in cooperation with state and local authorities. These roads should be all-weather roads that will allow access for the purpose of inspection, maintenance, and flood-fighting operations.

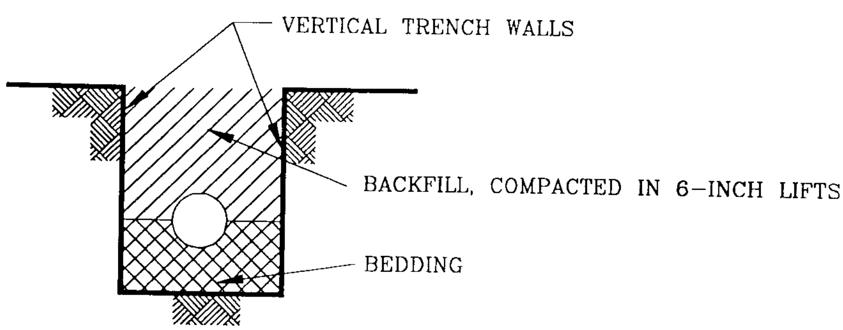
b. Access road on levee. Access roads, sometimes referred to as patrol roads, should be provided also on top of the levees for the general purpose of inspection, maintenance, and flood-fighting operations. This type of road should be surfaced with a suitable gravel or crushed stone base course that will permit vehicle access during wet weather without causing detrimental effects to the levee or presenting safety hazards to the levee inspection and maintenance personnel. The width of the road surfacing will depend upon the crown width of the levee, where roadway additions to the crown are not being used, and upon the function of the roadway in accommodating either one- or two-way traffic. On levees where county or state highways will occupy the crown, the type of surfacing and surfacing width should be in accordance with applicable county or state standards. The decision as to whether the access road is to be opened to public use is to be made by the local levee agency which owns and maintains the levee.

(1) Turnouts. Turnouts should be used to provide a means for the passing of two motor vehicles on a one-lane access road on the levee. Turnouts should be provided at intervals of approximately 762 m (2500 ft), provided there are no ramps within the reach. The exact locations of the turnouts will be dependent upon various factors such as sight distance, property lines, levee alignment, and desires of local interests. An example turnout for a levee with a 3.65 m (12-ft) levee crown is shown in Figure 8-4.

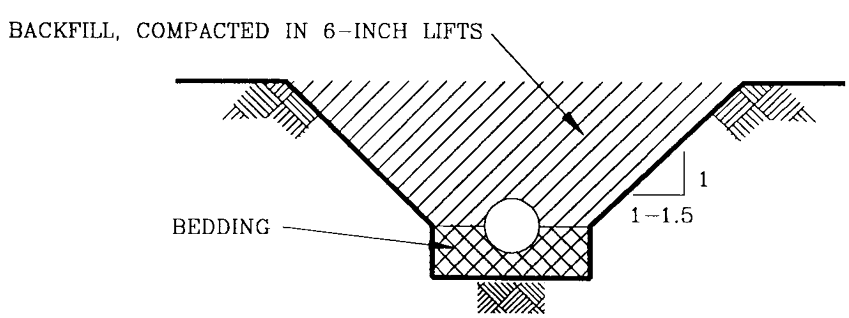
(2) Turnarounds. Turnarounds should be provided to allow vehicles to reverse their direction on all levees where the levee deadends, and no ramp exists in the vicinity of the deadend. An example turnaround for a levee with a 3.65-m (12-ft) crown is shown in Figure 8-5.



a. Detail of end casing (for pipe lines beneath the levees)



b. On riverside, within 50 ft of levee (for pipe lines cross-up and over-levees)



c. On landside (for pipelines cross-up and over-levees)

Figure 8-3. Details of pipeline levee crossing

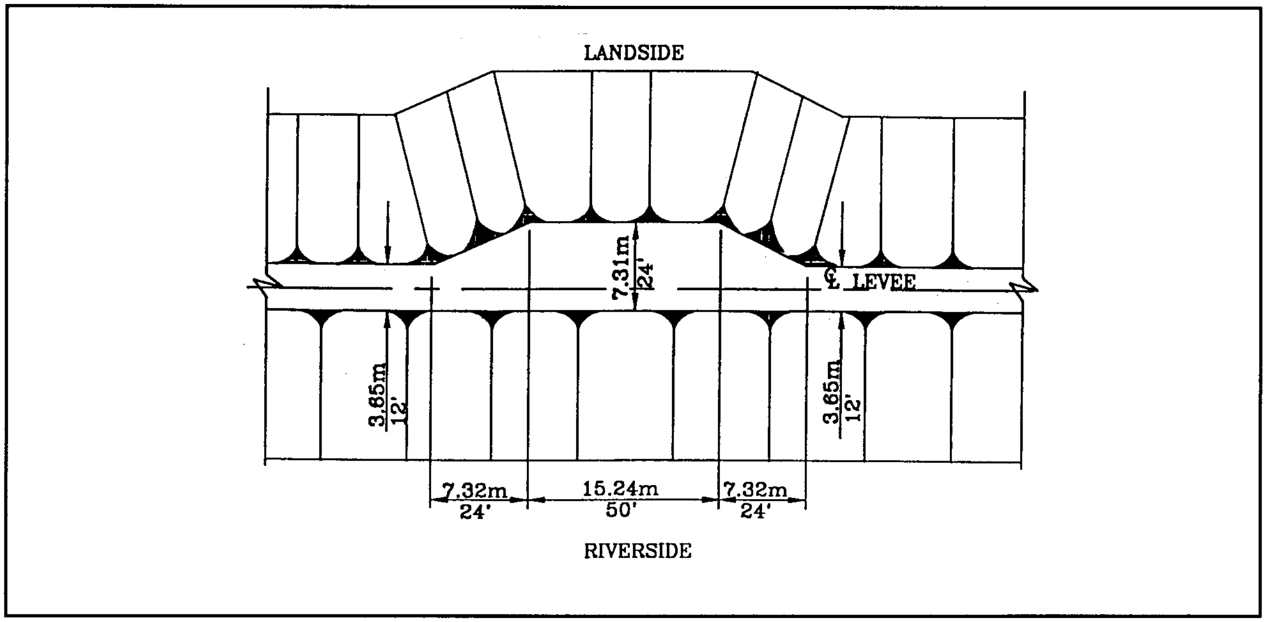


Figure 8-4. Example of levee turnout

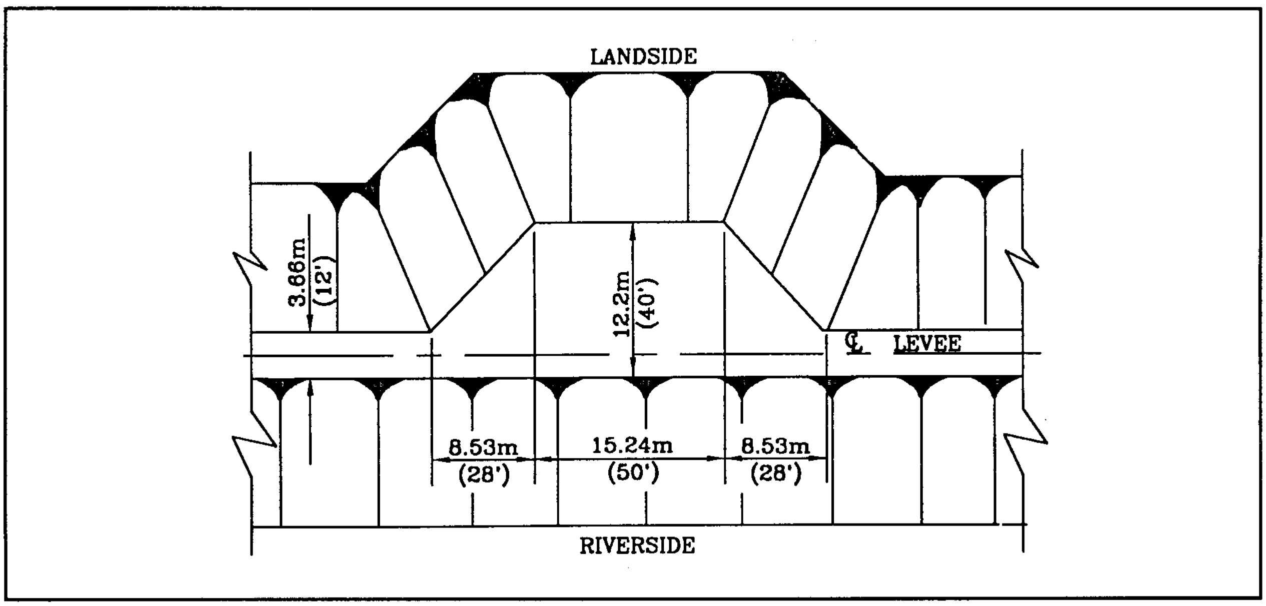


Figure 8-5. Example of levee turnaround

8-10. Ramps

a. Ramps should be provided at sufficient locations to permit vehicular traffic to access onto and from the levee. Ramps may be located on both the landside and the riverside of the levee. Ramps on the landside of the levee are provided to connect access roads leading to a levee with access roads on top of a levee and at other convenient locations to serve landowners who have property bordering the levee. Ramps are also provided on some occasions on the riverside of the levee to connect the access road on top of the levee with existing levee traverses where necessary. The actual locations of the ramps should have the approval of the local levee agency which owns and maintains the levee. When used on the riverside of the levee, they should be oriented to minimize turbulence during high water.

b. Ramps are classified as public or private in accordance with their function. Public ramps are designed to satisfy the requirements of the levee owner: state, county, township, or road district. Private ramps are usually designed with less stringent requirements and maximum economy in mind. Side-approach ramps should be used instead of right angle road ramps because of significant savings in embankment. The width of the ramp will depend upon the intended function. Some widening of the crown of the levee at its juncture with the ramp may be required to provide adequate turning radius. The grade of the ramp should be no steeper than 10 percent. Side slopes on the ramp should not be less than 1V on 3H to allow grass-cutting equipment to operate. The ramp should be surfaced with a suitable gravel or crushed stone. Consideration should be given to extending the gravel or crushed stone surfacing to the levee embankment to minimize erosion in the gutter. In general, private ramps should not be constructed unless they are essential and there is assurance that the ramps will be used. Unused ramps lead to maintenance neglect.

c. Both public and private ramps should be constructed only by adding material to the levee crown and slopes. The levee section should never be reduced to accommodate a ramp.

Section III
Levee Enlargements

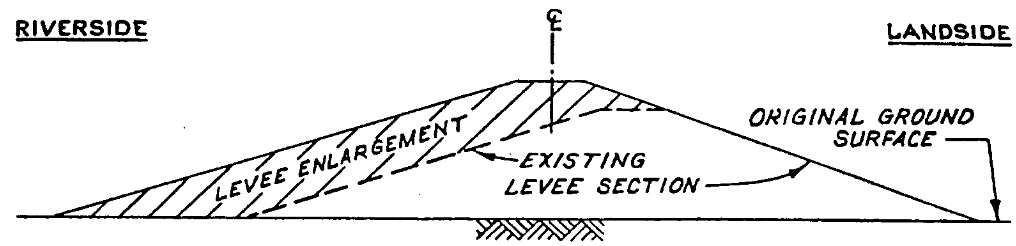
8-11. General

The term levee enlargement pertains to that addition to an existing levee which raises the grade. A higher levee grade may be required for several reasons after a levee has been constructed. Additional statistical information gathered from recent floodings or recent hurricanes may establish a higher project flood elevation on a river system or a higher elevation for protection from incoming tidal waves produced by hurricane forces in low-lying coastal areas. The most economical and practical plan that will provide additional protection is normally a levee enlargement. Levee enlargements are constructed either by adding additional earth fill or by constructing a flood-wall, "I"-type or "inverted T"-type, on the crown.

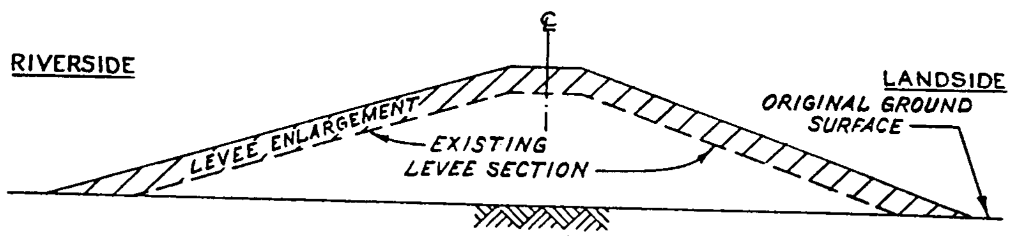
8-12. Earth-Levee Enlargement

a. The earth-levee enlargement is normally preferred when possible, since it is usually more economical. This type of enlargement is used on both agricultural and urban levees where borrow sites exist nearby and sufficient right-of-way is available to accommodate a wider levee section.

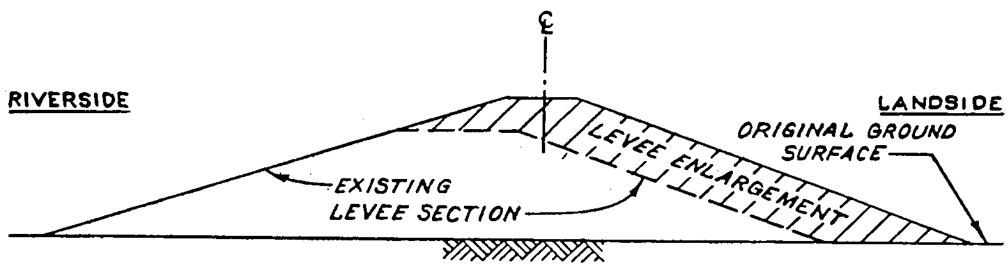
b. An earth-levee enlargement is accomplished by one of three different methods: riverside, straddle, or landside enlargement. A riverside enlargement is accomplished by increasing the levee section generally at the crown and on the riverside of the levee as shown in Figure 8-6a. A straddle enlargement is accomplished by increasing the levee section on the riverside, at the crown, and on the landside of the levee-as shown in Figure 8-6b. A landside enlargement is accomplished by increasing the levee section, generally at the crown and on the landside of the levee as shown in Figure 8-6c. There are advantages and disadvantages to each enlargement method that will have to be looked at for each project. The riverside enlargement would be more costly if the riverside slope has riprap protection and it could also be an encroachment for narrow floodways that would impact top of levee designs. Landside enlargements would require additional right-of-way and larger fill quantities for levees with flatter landside slopes. The strattle enlargement would require the whole levee system to be stripped with work being done on both sides of the levee.



a. **Riverside levee enlargement**



b. **Straddle levee enlargement**



c. **Landside levee enlargement**

Figure 8-6. Enlargements

c. The modified levee section should be checked for through seepage and underseepage as discussed in Chapter 5 and for foundation and embankment stability as discussed in Chapter 6. Sufficient soil borings should be taken to determine the in situ soil properties of the existing levee embankment for design purposes.

d. An earth-levee enlargement should be made integral with the existing levee. Every effort should be made such that the enlargement has at least the same degree of compaction as the existing levee on which it is constructed. Preparation of the interface along the existing levee surface and upon the foundation should be made to ensure good bond between the enlargement and the surfaces on which it rests. The foundation surface should be cleared, grubbed, and stripped as described in Chapter 6. The existing levee surface upon which the levee enlargement is placed should also be stripped of all low-growing vegetation and organic topsoil. The topsoil that is removed should be stockpiled for reuse as topsoil for the enlargement. Prior to constructing the enlargement, the stripped surfaces of the foundation and existing levee should be scarified before the first lifts of the enlargements are placed.

8-13. Floodwall-Levee Enlargement

a. A floodwall-levee enlargement is used, when additional right-of way is not available or is too expensive or if the foundation conditions will not permit an increase in the levee section. Economic justification of floodwall-levee enlargement cannot usually be attained except in urban areas. Two common types of floodwalls that are used to raise levee grades are the I wall and the inverted T wall.[1]

b. The I floodwall is a vertical wall partially embedded in the levee crown. The stability of such walls depends upon the development of passive resistance from the soil. For stability reasons, I floodwalls rarely exceed 2.13 m (7 ft) above the ground surface. One common method of constructing an I floodwall is by combining sheet pile with a concrete cap as shown in Figure 8-7. The lower part of the wall consists of a row of steel sheet pile that is driven into the levee embankment, and the upper part is a reinforced concrete section capping the steel piling.

c. An inverted T floodwall is a reinforced concrete wall whose members act as wide cantilever beams in resisting hydrostatic pressures acting against the wall. A typical wall of this type is shown in Figure 8-8. The inverted T floodwall is used to make floodwall levee enlargements when walls higher than 2.13 m (7 ft) are required.

d. The floodwall should possess adequate stability to resist all forces which may act upon it. An I floodwall is considered stable if sufficient passive earth resistance can be developed for a given penetration of the wall into the levee to yield an ample factor of safety against overturning. The depth of penetration of the I wall should be such that adequate seepage control is provided. Normally the penetration depth of the I wall required for stability is sufficient to satisfy the seepage requirements. For the inverted T floodwall, the wall should have overall dimensions to satisfy the stability criteria and seepage control as presented in EM 1110-2-2502.

e. The existing levee section should be checked for through seepage and underseepage as discussed in Chapter 5 and for embankment and foundation stability as discussed in Chapter 6 under the additional hydrostatic forces expected. If unsafe seepage forces or inadequate embankment stability result from the higher heads, seepage control methods as described in Chapter 5 and methods of improving embankment stability as described in Chapter 6 may be used. However, some of these methods of controlling seepage and improving embankment stability may require additional right-of-way for construction which could eliminate the economic advantages of the floodwall in comparison with an earth levee enlargement. As in earth levee enlargements, a sufficient number of soil borings should be taken to determine the in situ soil properties of the existing levee embankment for design purposes.

[1] Structural design of crest walls is given in ETL 1110-2-341.

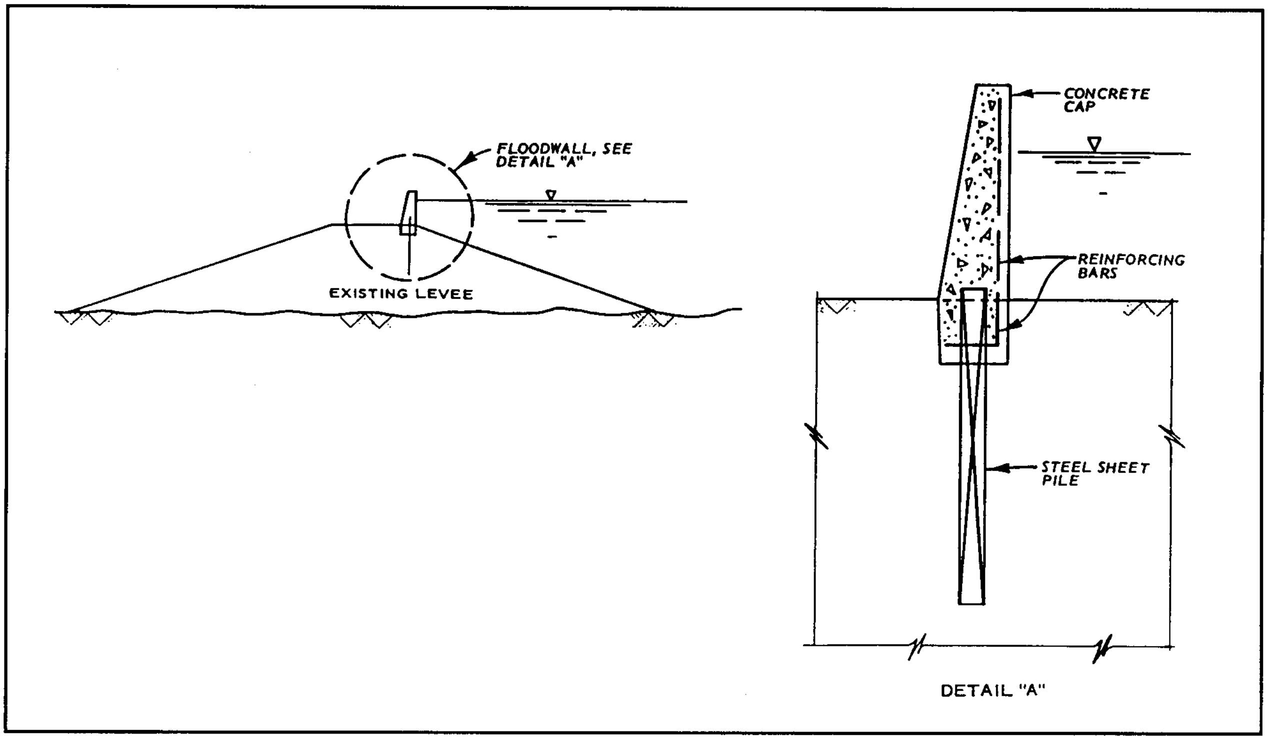


Figure 8-7. I-type floodwall-levee enlargement

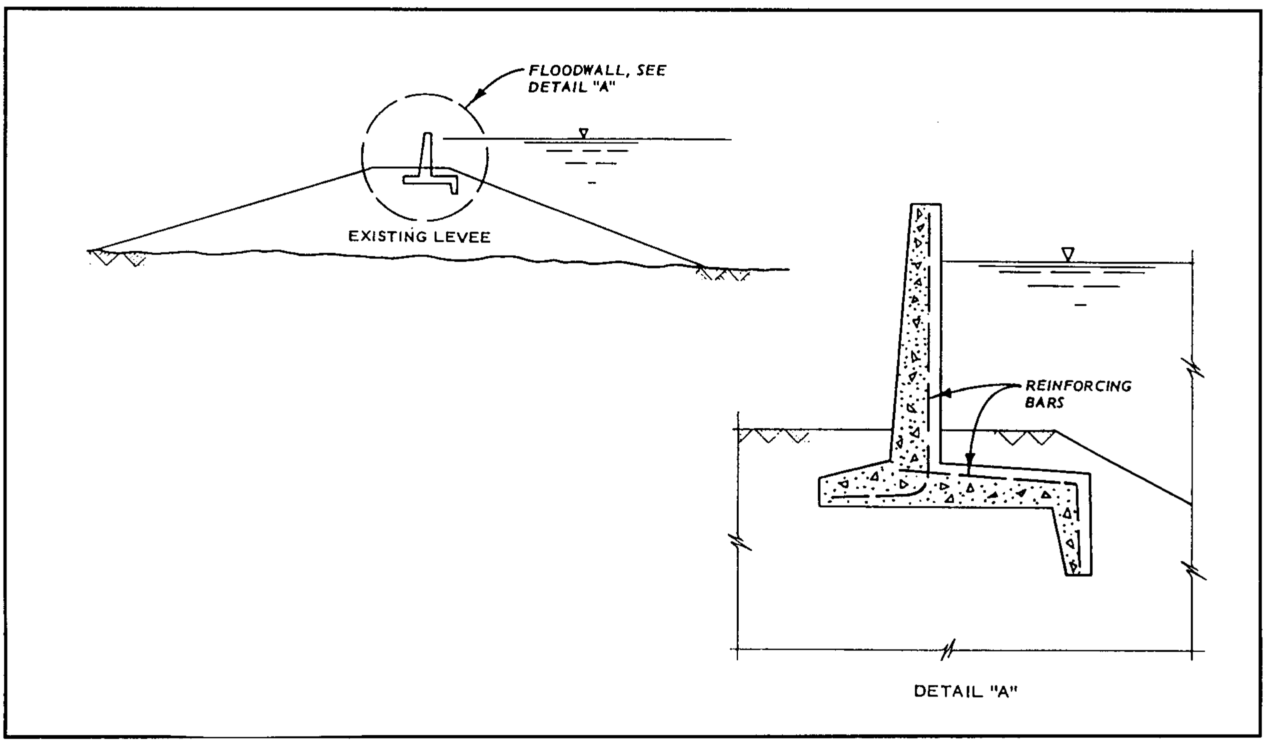


Figure 8-8. Inverted T-type floodwall-levee enlargement

Section IV
Junction with Concrete Closure Structures

8-14. General

In some areas, a flood protection system may be composed of levees, floodwalls, and drainage control structures (gated structures, pumping plants, etc.). In such a system, a closure must be made between the levee and the concrete structure to complete the flood protection. One closure situation occurs when the levee ties into a concrete floodwall or a cutoff wall. In this closure situation the wall itself is usually embedded in the levee embankment. In EM 1110-2-2502 a method of making a junction between a concrete floodwall and levee is discussed and illustrated. Another closure situation occurs when the levee ties into a drainage control structure by abutting directly against the structure as shown in Figure 8-9. In this situation the abutting end walls of the concrete structure should be battered 10V on 1H to ensure a firm contact with the fill.

8-15. Design Considerations

When joining a levee embankment with a concrete structure, items that should be considered in the design of the junction are differential settlement, compaction, and embankment slope protection.

a. Differential settlement. Differential settlement caused by unequal consolidation of the foundation soil at the junction between a relatively heavy levee embankment and a relatively light concrete closure structure can be serious if foundation conditions are poor and the juncture is improperly designed. Preloading has been used successfully to minimize differential settlements at these locations. In EM 1110-2-2502 a transitioning procedure for a junction between a levee embankment and a floodwall is presented that minimizes the effect of differential settlement.

b. Compaction. Thorough compaction of the levee embankment at the junction of the concrete structure and levee is essential. Good compaction decreases the permeability of the embankment material and ensures a firm contact with the structure. Heavy compaction equipment such as pneumatic or sheepsfoot rollers should be used where possible. In confined areas such as those immediately adjacent to concrete walls, compaction should be by hand tampers in thin loose lifts as described in EM 1110-2-1911.

c. Seepage. Seepage needs to be analyzed to determine the embedment length of the structure-levee junction. Zoning of the embankment materials needs to be maintained through the junction unless analysis indicates different zoning is required.

d. Slope protection. Slope protection should be considered for the levee embankment at all junctions of levees with concrete closure structures. Turbulence may result at the junction due to changes in the geometry between the levee and the structure. This turbulence will cause scouring of the levee embankment if slope protection is not provided. Slope protection for areas where scouring is anticipated is discussed in paragraph 7-6.

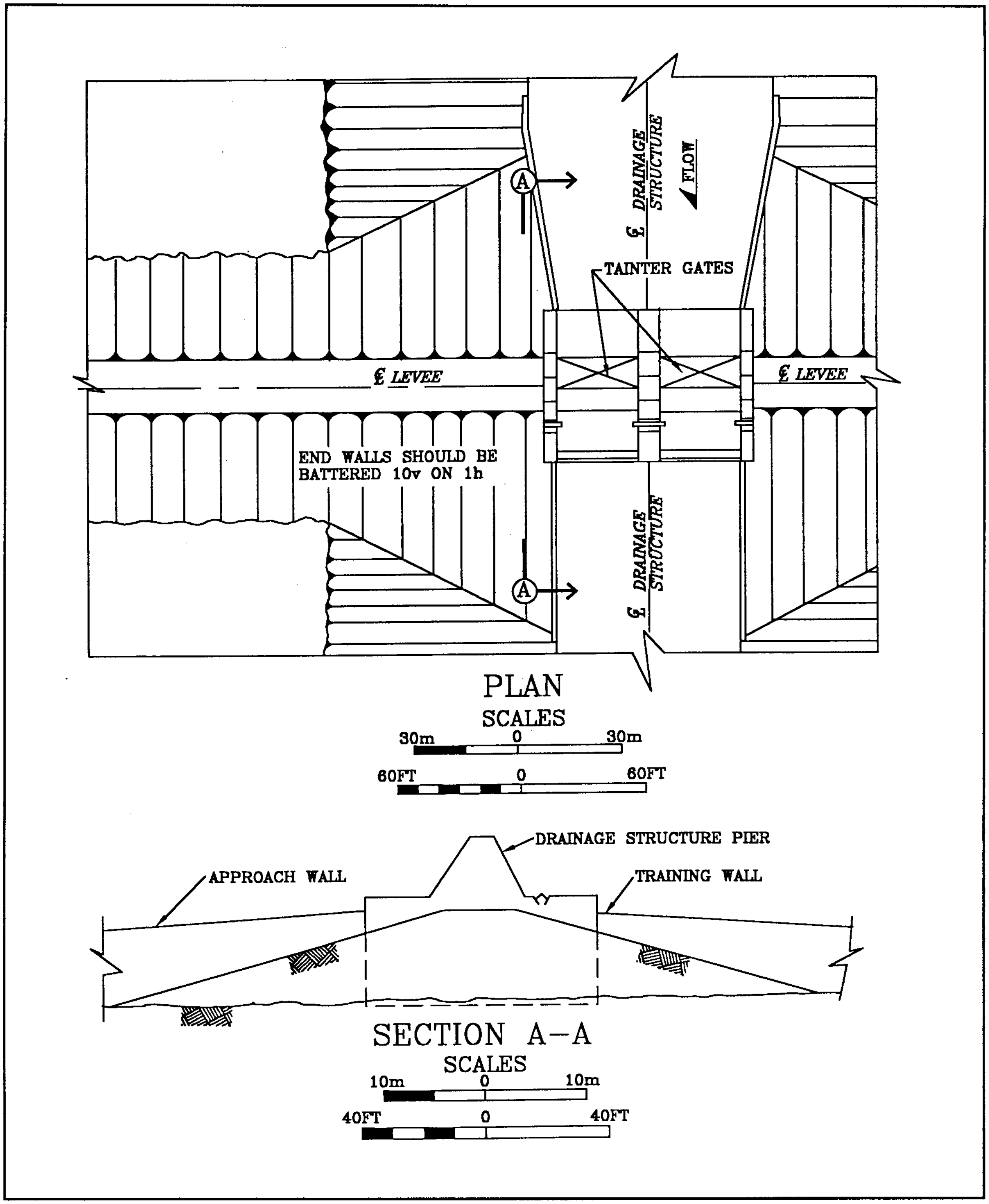


Figure 8-9. Junction of levee and drainage structure

Section V
Other Special Features

8-16. Construction of Ditches Landside of Levee

Sometimes requests are made to locate irrigation and/or drainage ditches in close proximity to the landside levee toe. Such ditches may lead to serious seepage and/or slope stability problems. The location and depth of proposed ditches should be established by seepage and stability analyses. This requires information on foundation soil conditions, river stages and geometry of the proposed ditch.

Drainage ditches should be located such that the exit gradient in the bottom of the ditch does not exceed 0.5 at the landside levee toe and does not exceed 0.8 at a distance 45.72 m (150 ft) landward of the landside levee toe and beyond. Between the landside levee toe and 45.72 m (150 ft) landward of the landside levee toe, the maximum allowable exit gradient in the bottom of the ditch should increase linearly from 0.5 to 0.8. The exit gradient should be computed assuming the water level in the ditch is at the bottom of the ditch.

8-17. Levee Vegetation Management

To protect or enhance esthetic values and natural resources, vegetation on a levee and its surrounding areas (trees, bushes and grasses) is an important part of design considerations. Vegetation can be incorporated in the project as long as it will not diminish the integrity and the functionality of the embankment system or impede ongoing operations, maintenance and floodfighting capability. A multidiscipline team including structural and geotechnical engineers, biologists and planners should evaluate the vegetation design or proposal. Coordination with local governments, states and Native American tribes may be needed during the design process. EM 1110-2-301 and ER 500-1-1 are two documents covering the vegetation policy applicable to both federal levees and non-federal levees under the PL-84-99 program.